



THE  
JOURNAL OF ECONOMIC BIOLOGY.

---

PRELIMINARY OBSERVATIONS UPON THE LIFE-  
HISTORIES OF *ZENILLIA PEXOPS*, B. & B.,  
AND *HYPAMBLYS ALBOPICTUS*, GRAV.

(Two previously unrecorded parasites of the Large Larch Sawfly).

By R. A. WARDLE, M.Sc. (VICT.),

Lecturer in Economic Zoology in the University of Manchester.

(WITH PLATES IV-VI AND ONE TEXT-FIGURE).

CONTENTS.

	PAGE
1. Introduction - - - - -	85
2. Hymenopterous parasites of <i>Nematus erichsonii</i> - - -	86
3. Dipterous parasites of <i>Nematus erichsonii</i> - - -	96
4. Conclusions from Economic Standpoint - - - - -	100
5. Summary - - - - -	103

I.—INTRODUCTION.

The investigation into the methods of controlling the ravages of the Large Larch Sawfly (*Nematus erichsonii*, Htg.) in the Manchester Corporation Estates at Thirlmere, Cumberland, was continued by the Department of Economic Zoology at Manchester, during 1913 and 1914, chiefly with a view to eliciting further information which might bear upon the policy, that is being pursued, of encouraging the natural agencies that tend to keep the pest in check. A large part of the material and data upon which this paper is based was gathered together by my predecessor, Mr. Joseph Mangan, and I must express my indebtedness to him for permission to utilise the same. The inquiry into the percentage-numbers of insect-parasites of the Sawfly has yielded during the past two years extremely interesting and important results. The most noteworthy features have been the great reduction in the percentage numbers of *Mesoleucis tenthredinis*, Morley—the Ichneumonid parasite so prevalent in previous years—and the increase in the numbers of two parasites that have hitherto played an extremely insignificant part in the checking of the Sawfly, namely:—

(1). *Hypamblys albopictus*, Grav., an Ichneumonid closely related to *Mesoleius*.

(2). *Zenillia pexops*, B. and B., a Tachinid fly.

Neither had been recorded from the Large Larch Sawfly prior to the publication, in *Nature*, of July 24th, 1913, of Mr. Mangan's letter announcing these results, although there is no doubt that both parasites have been present since the investigation was first commenced.

## 2.—HYMENOPTEROUS PARASITES OF *Nematus erichsonii*.

The Hymenopterous parasites that have previously been reared from *Nematus erichsonii* are as follows:—

### Family Ichneumonidae.

#### Sub-family Ichneumoninae.

<i>Coelichneumon fuscipes</i> , Grav. ...	1910	Thirlmere.
<i>Cratichneumon annulator</i> , Fab. ...	1911	Thirlmere.

#### Sub-family Cryptinae.

<i>Microcryptus labralis</i> , Grav. ...	1909 onwards	Thirlmere.
<i>Aptesis nigrocincta</i> , Forster. ...	1910 and 1911	Thirlmere.
<i>Spilocryptus incubitor</i> , Strom. ...	1911	Thirlmere.
<i>Cryptus minator</i> , Grav. ...	1910	Thirlmere.
* <i>Hemiteles necator</i> , Grav. ...	1910	Thirlmere.

#### Sub-family Tryphoniinae.

<i>Mesoleius tenthredinis</i> , Morley. ...	1908 onwards	Thirlmere.
<i>Perilissus filicornis</i> , Grav. ...	Recorded by Cameron	(1885).
<i>Perilissus lutescens</i> , Grav. ...	Recorded by Brischke.	

### Family Braconidae.

<i>Microgaster</i> sp. ...	Recorded by Lintner	(1885).
* <i>Microplites</i> sp. ...	1911	Thirlmere.

### Family Chalcididae.

<i>Coelopisthia nematicida</i> , Pack. ...	Maine	(1883).
<i>Diglochis</i> sp. (prob. klugii). ...	Minnesota	(1909).
<i>Pteromalus</i> ( <i>Diglochis</i> ) <i>klugii</i> . ...	Posen	(1841).
* <i>Perilampus</i> sp. ...	Wisconsin	(1910).

### Family Cynipidae.

* <i>Anacharis typica</i> . ...	Thirlmere	(1910).
* <i>Figites</i> sp. ...	Thirlmere	(1910).

\* Probably hyperparasites.

The majority of the parasites were reared at Manchester and at Ottawa; a fuller account of the majority of these parasites is given by Hewitt. (1). No Chalcid has, it will be noted, been recorded from English cocoons, but an unidentified chalcid was reared from a Buttermere cocoon in 1913, and may prove to be an unrecorded parasite.

In spite of the length of this list, in the majority of cases only one or two specimens of the parasite have ever been obtained, possibly because they are normally parasites of Lepidoptera and only accidentally parasites of *Nematus*. In fact, the only species which has occurred in successive years in sufficient numbers to have been of economic interest is the Ichneumon *Mesoleius tenthredinis*. That this parasite should persist year after year is only to be expected, for the sub-family, Tryphoninae, to which it belongs is very largely parasitic upon Tenthredinidae. This ichneumon occurred to the extent of 6 per cent. in Sawfly cocoons from Thirlmere in 1908; this proportion in 1910 had risen to 62 per cent., and the plantations during that year were almost wholly free from attack. The reduction in the number of Sawflies was naturally followed by a reduction in the number of *Mesoleius tenthredinis*, the percentage in 1911 falling to 18, and in 1912 to 8. In 1913 the percentage was even less. These figures apply to cocoons from the Thirlmere district. The percentage number of *Mesoleius* in cocoons from other localities was, in 1913, still fairly high, as will be seen from the subjoined table:—

REARING RESULTS, 1913.

Locality.	No. of Cocoons.	Per that hatched	Proport. of <i>M. tenthredinis</i>	<i>H. albopictus</i>	<i>Z. pexops</i> .
Thirlmere (Shoulthwaite) ...	1295	41 %	2 %	25 %	24 %
Keswick (Latrigg) ...	266	34 %	15 %	4 %	56 %
„ (Coombe) ...	460	33 %	8 %	28 %	18 %
Buttermere ...	80	36 %	32 %	14 %	None
Crummock (Lanthwaite) ...	537	44 %	10 %	7 %	2·2 %
Grasmere (Wyke) ...	238	54 %	35 %	1 %	None
Ambleside (Long Heights)*	?	?	51·8 %	14·3 %	?

\* Data for Long Heights supplied by Dr. C. Gordon Hewitt.

The percentages given above do not represent actual percentages of the quantities of cocoons taken, but merely represent the ratio of parasites to Sawflies in the cocoons that hatch. This is due to the fact that some 50 per cent. or more of the cocoons do not yield any results, the caterpillars either perishing from fungus, drought or disease, or refraining from pupation until the succeeding year. The Board of Agriculture rearing experiments, carried out in well ventilated breeding boxes placed in the woods at Rhayader, also only yielded a hatching percentage of 33.1. (2). As the fungus occurs naturally in the woods, attacking even 25 per cent. of the cocoons according to Hewitt, there is no doubt that this loss of cocoons in the breeding cages is inevitable and to a certain extent paralleled under natural conditions. As some of these localities were exploited for the first time in 1913, it is not possible in every case to say whether an actual decrease in the percentage of the species has occurred in 1913, as compared with 1912. Those cases in which comparison can be made, however, do indicate a very considerable decrease, and it is possible that this holds good in every case: thus, the apparently high percentage of 51 in Ambleside cocoons is a reduction from percentage of 75 and 56 in two respective batches of cocoons reared in 1912; similarly the Grasmere percentage of 35 is a reduction from 82, and the Crummock percentage has declined from 24 to 10.

A reduction from a high percentage in one year to a much lower percentage in the succeeding year is only to be expected, if correlated with a gradual decline in the numbers of the host, particularly if the former percentage be abnormally high, as was the case in 1912 among Grasmere and Ambleside cocoons. There is, however, some reason to suspect that this percentage decline in the numbers of *Mesoleius* has not in every case been accompanied by a corresponding reduction in the numbers of the *Nematus*. Thus, Shoulthwaite plantation, with a decline in the percentage of *Mesoleius* from 8 to 2, was distinctly worse in 1913 than in the previous year. Under such circumstances, therefore, it is extremely suspicious to find such a decline accompanied by a considerable increase in the numbers of two other parasites, even though there can be absolutely no question as to their being also primary parasites of *Nematus*.

Among the parasites reared from Thirlmere cocoons in 1910, there appeared certain specimens of an Ichneumon which, though resembling *Mesoleius tenthredinis*, was yet sufficiently distinguishable from it by the white colour of the first and second coxae.

Examination of 1909 material showed that a few specimens had also been reared in that year also. In 1911 and 1912 comparatively

few cocoons were obtained and no specimens of this ichneumon were reared here, although I understand from Dr. Hewitt that he reared it in Canada (from Thirlmere cocoons) during that period. No proper identification appears ever to have been made, although the insect was alluded to by Mangan (3), until last year, when, comparatively large numbers having been reared from Shoulthwaite and Coombe cocoons, specimens sent to Professor Schmiedeknecht were identified as *Hypamblys albopictus*, Grav., and described as having never before been recorded from *Nematus erichsonii*. A note of this fact was published in *Nature* (Nov. 13, 1913) where, by an unfortunate error, the generic name appeared as "*Hyperamblys*." I take this opportunity, therefore of correcting the same.

<i>Hypamblys albopictus</i> , Grav.	} Synonyms.
<i>Tryphon albopictus</i> , Grav.	
<i>Euryproctus transfuga</i> , Thomson.	
<i>Euryproctus albopictus</i> , Strobl.	
<i>Syndipnus albopictus</i> , Pfankuch.	
<i>Mesoleius transfuga</i> , Holmgren.	

*Description*.—This species is described by Schmiedeknecht in *Opuscula Ichneumonologica* (p. 2791) as *Hypamblys albopictus*, and by Morley in *British Ichneumons* (Vol. IV, p. 248) under the name *Euryproctus albopictus*. The following description is quoted from the latter source :—

"A shining, punctulate species, with hind tibiae mainly white and abdomen more or less broadly red centrally. Head somewhat constricted posteriorly; mouth, clypeus and, except a black line connecting it with clypeus, face whitish; Clypeus apically broadly rounded, hardly margined and basally sub-discreted; cheeks black and not buccate. Antennae filiform, as long as body and more slender in male; scape whitish beneath; five or more basal flagellar joints whitish—testaceous, becoming apically darker. Thorax white—dotted below radices; mesonotum convex with indistinct notauli, pleurae nitidulous; metathorax subrugulose, with areola wanting or very incomplete, petiolar area smooth and entire. Abdomen nitidulous, apically explanate in male and sub-compressed in female, black; male with second segment, except two discal dots, third entirely and a trans fascia on fourth, red, or with only the second segment apically ferruginous in both sexes; remainder apically flavescent-margined; basal segment very slightly curved and subdistinctly sulcate distally to beyond its centre, with central spiracles; ventral plica flavous, hypopygium extending to sixth dorsal segment; terebra short and infusate. Legs fulvous, anterior

with coxae and trochanters of male whitish; hind coxae black and in male apically, with trochanters, whitish; hind tibiae in both sexes whitish with apices, apices of their femora, and all their tarsi, nigrescent. Wings hyaline, stigma and radius infuscate, radix and tegulae white; areolet wanting or irregularly subpetiolate; nervellus intercepted a little below centre. Length, 6 mm."

With regard to the hosts of this ichneumon, Morley adds:—

"This collective species occurs in Silesia, Belgium and France, and from the end of July to early September, in Southern Sweden; it was bred by Brischke (Schr. Nat. Ges. Danz., 1871, p. 80) from larvae of *Nematus hypogastricus*, and of *N. testaceus* in Prussia. *E. albopictus* was recorded by Marquand from the Lands End district (Trans. Penz. Nat. Hist. Soc., 1884, p. 346), and by Bridgeman from Brundall, in Norfolk, during July and August. *M. transfuga* was also brought forward by the latter, with some hesitation (Trans. Norf. Soc., 1894, p. 625), from Kings Lynn, in the same country, and bred, probably at Worcester from *Camponiscus luridiventris* by Fletcher."

*Camponiscus luridiventris* is, according to Cameron, synonymous with *Nematus hypogastricus*. So that in endeavouring to ascertain the possible origin of the appearance of *Hypamblys albopictus* in the Larch plantations we have only two previously recorded hosts to take into consideration, namely: *Nematus flavescens* (testaceous), Ste., a common insect on *Salix caprea*, and *Camponiscus luridiventris*, Fall, a widespread feeder on the Alder. It is extremely likely then that this Ichneumon has always been present in the vicinity of the Larch plantations as a parasite of the caterpillars upon Willows and Alders, but owing to the fact that these caterpillars are not numerous enough to become pests, has never been able to increase to a great extent and so come into prominence, until afforded an opportunity by the sudden outbreak of *N. erichsonii*.

*Life-history*.—Dissections of parasitised *Nematus* caterpillars at various times during the past eighteen months have yielded a considerable quantity of Ichneumonid larvae. To diminish the possibility of these larvae belonging to both *Mesoleius tenthredinis* and *Hypamblys albopictus*, the caterpillars dissected were taken solely from Shoulthwaite cocoons, the proportion of *Mesoleius* in this locality being only 2 per cent. of *Hypamblys* during the period covering dissections. It may be pointed out, however, that the scanty information available regarding the life cycle of Ichneumonids seems to indicate that the larvae of closely related species, parasitic on coincident stages of the same host or allied hosts, would be extremely difficult, if not impossible, to distinguish, and that when the times of imaginal

emergence agree, as in this case, the times of duration of the various stages probably agree also. The tentative reconstruction of the life-history of *Hypamblys albopictus* described below, is therefore, I believe, not vitiated by the possible intrusion of specimens of *Mesoleius* larvae into the material under examination.

*Dates of Emergence.*—The dates of emergence of *Hypamblys* from the Sawfly cocoons agree fairly closely with those of *Mesoleius*; both began to appear in 1913, during the last week in April or the first fortnight in May. The earliest emergence recorded for *Hypamblys* was on April 26th, and the majority had emerged before the end of May, the last recorded emergence being recorded on June 10th. The natural time for *Hypamblys* to commence to emerge is probably the first fortnight in May. In 1914 they commenced to emerge so early as April, but as the cocoons from which they emerged had been kept indoors throughout the winter, this early emergence cannot be taken as normal. As will be seen from the sub-joined table, the *Ichneumon* commences to emerge some time after the first date of emergence of the host, some nineteen to twenty-five days after, in fact.

DATES OF EARLIEST EMERGENCE.

Locality.	1913.		1914.	
	<i>N. erichsonii</i>	<i>H. albopictus</i>	<i>N. erichsonii</i>	<i>H. albopictus</i>
Shoulthwaite ... ..	April 29	April 30	Feb. 28	April 2
" ... ..			Mar. 11	April 14
Buttermere... ..	April 24	May 13		May 14
Grassmere (Wyke) ... ..	April 15	May 10	April 27	May 16
Dodd ... ..			April 21	May 11
" ... ..			April 21	May 13
Latrigg ... ..	April 25	May 8		
Coome ... ..	April 15	May 10		

*Oviposition.*—As regards the number of eggs that the *Ichneumon* can lay, no definite statement can be made. As each ovary, however, contains twenty-eight tubules, and as at least eight ova, in various stages of maturity, are discernible in each tubule, the number of eggs that the *Ichneumon* is capable of producing cannot be less than 448, and



probably greatly exceeds this number. I have not yet been fortunate enough to observe the actual process of oviposition: all the Ichneumons reared in captivity during 1914 emerged, and died, some weeks before Larch Sawfly Caterpillars were procurable, and numerous attempts to induce the parasites to oviposit in the similar caterpillars of *Nematus ribesii* were fruitless. Mr. Edwards, however, has observed *Hypamblys* females ovipositing within medium sized Larch Sawfly caterpillars: the posterior half of the body was the region attacked.

A batch of caterpillars, however, produced in July, 1914, from the Thirlmere plantations, proved to contain freshly parasitised specimens and Ichneumon eggs in various stages of development were obtained, in addition to newly hatched larvae. The number of eggs and embryos found in parasitised caterpillars was, in the majority of cases, two; in the few cases where this number was exceeded the eggs were in various stages of development and probably had not been all deposited by one individual *Hypamblys*.

*Egg*.—The newly deposited egg (Pl. iv, fig. 2) measures about 5 mm. in length by 2 mm. in breadth; it is cucumber shaped, but with the ends rounded, and is a vitreous white in colour; the developing embryo is faintly discernable through the semi-transparent chorion. As the embryo develops, the egg lengthens somewhat, not apparently by a process of true growth but by a stretching of the chorion, which is thereby rendered thinner and more transparent. The end of the embryo destined to form the future head, and the developing appendages, are clearly demarcated (Pl. iv, fig. 3).

By further stretching of the chorion the egg becomes almost spherical in shape, and the embryo undergoes a ventral flexure until the future head end and the future tail end almost touch. The head and body segments now become clearly marked, and the abdominal appendages and the posterior appendages—the so-called “tail”—develops (Pl. iv, fig. 4). The egg is ready to hatch, the chorion being now so thin that a very slight prick, whether from the needle of the observer or the mandibles, presumably, of the embryo, is sufficient to rupture it and free the imprisoned embryo.

The duration of these stages is very difficult to estimate, as the actual time of oviposition was in no case known, but from knowledge of the probable ages of the caterpillars examined and the dates when they were collected, I should estimate the period between the oviposition and completion of embryonic development to be about fourteen days.

*First Stage Larva*.—The newly hatched larva (Pl. iv, fig. 5) averages slightly over 1 mm. in length by .22 mm. in breadth across the thoracic portion. The head is comparatively large, unpigmented

except for a pair of long pointed mandibles, reddish orange in colour, crossing each other at the tip and apparently hollow. Behind the head follows a trunk consisting of thirteen segments, the last of which is prolonged into a tail-like outgrowth, measuring one-fifth of the total, i.e., some 0.15 mm. in length. The trunk is made up of a thoracic portion of three large segments, each bearing a pair of lobe-like appendages, and an abdominal portion of ten smaller abdominal segments, each bearing a pair of claw-like appendages. These segments and appendages are better marked in the older larva. Timberlake (5), describing the similar larval stages of *Limnerium validum*, an Ophionine Ichneumon, distinguishes only twelve trunk segments. On the other hand Seurat (6) describing similar stages in the Ichneumon *Mesochorus vittator* distinguishes thirteen segments; Ratzeberg (7) also in describing the larval stages of *Anomalon circumflexum*, considers the number to be thirteen. Other authors also speak of the number of segments being thirteen; e.g., Riley in regard to *Thalessa lunator*, Berthoumieu in regard to *Ichneumon rubens*, Nambu in regard to *Pimpla oculatoria*. All agree in considering the tail to be a ventral outgrowth of the last segment: this organ is slender, tapering, curved slightly, and possibly serves a respiratory function.

Timberlake (5), describing a similar structure in the larva of *Limnerium validum*, an Ophionine Ichneumon, says:—" . . . the organ might properly be termed a blood gill. There is nothing in its structure to contradict this view, as it is a simple hollow tube lined with hypodermal cells, and undoubtedly filled with blood a greater part of the time. Since the larva lies free in the body cavity of the host, it is constantly bathed in blood and lymph fluids, from which the oxygen of its own blood must be derived through the delicate integument of the tail or other parts of the body, especially while still small."

Seurat, however, and Morley also, ascribe a locomotory function to this outgrowth.

The respiratory system agrees very closely with Seurat's description of the respiratory system of *Mesochorus*, consisting as it does of two lateral trunks running from thorax to tail, each sending off a latero-dorsal and a latero-ventral branch to each segment, and branches to the head; the prothoracic commissure connecting the two lateral trunks was quite obvious, but the ventral commissure at the anterior end of the tail was not discernible but may have been present. Stigmata were not discernable. According to Seurat, the tracheal system at this stage is a closed one, air being taken into the tracheal trunks via the skin, and the stigmatic trunks being blind at their free extremities.

The full-grown larva of this stage (Pl. v, fig. 6) averages somewhat over 4 mm. in length, the trunk being 3 mm. in length, and the tail 1 mm. In structure it resembles the newly hatched form, the head being, however, well chitinised and more definite in shape, and the segments and appendages being more clearly demarcated. The mouth-parts (Pl. v, fig. 7) consist of strong, pointed mandibles projecting across a circular mouth cavity, the chitinous rim of which is somewhat indented on the posterior margin.

Apparently this full-grown larva does not feed but lies dormant until the following Spring. Parasitised caterpillars examined early in November, contained these full-fed first stage larvae, lying in the fat body and occurring singly or in numbers, the usual number being two or three. Examination of parasitised caterpillars in the following March yielded the same stage of the larva, the specimens being identical in size and structure with those obtained three months before, and the fat-body of the caterpillar appearing in no ways different from that of the caterpillars in November.

A curious feature about this stage is that it is quite a common occurrence to find full grown, fully-developed larva still apparently within the swollen egg. This phenomenon naturally brings about the question as to whether the free first stage larvae found, had hatched naturally or whether they had been liberated artificially in the process of caterpillar examination. It also leads one to suspect that this first stage larva may not feed upon the caterpillar at all, but remain within the egg and complete its first stage growth at the expense of it. The question is one that requires further investigation. I can find no mention of it in such literature as I have been able to consult. Timberlake certainly mentions having found larvae enclosed in a "thick, homogeneous-appearing transparent capsule of tissue," but he states that the larvae were dead and that this capsule was composed of innumerable closepacked, amoebocytes serving to break down the tissues of the enclosed parasites.

*Second Stage Larva.*—(Pl. v, fig. 8). In the Spring the first-stage larva becomes active again and moults into the second stage. Examination of parasitised caterpillars in March yielded, in addition to numerous first stage larvae, certain other larval forms, slightly larger in size but differing chiefly in possessing a soft, less chitinised head, a reduction in the size of the abdominal appendages and a comparatively small tail. Only one second stage larva seems to occur in a caterpillar, though it may be accompanied by several first-stage larvae. Very few of these second-stage larvae were found.

The larva is about 6 mm. long, and consists of a head, very

similar in size and shape to that of the first stage, but quite soft and unpigmented, and a trunk of thirteen segments, the last of which is prolonged ventrally into a short tail-like appendage. The segments are not so clearly demarcated as in the first stage, and cannot be differentiated into thoracic and abdominal portions. The appendages are greatly reduced. The mouth-parts consist of a pair of mandibles, not very clearly marked, projecting across a circular, funnel-like mouth cavity.

There is no doubt that, when several first stage larvae occur in one caterpillar, only one of these passes over into the succeeding stages. Not only does the size of the imago militate against the possibility of more than one emerging from a single cocoon, but examination of numerous parasitised cocoons in April has never yielded more than one Ichneumon pupa to a cocoon. Whether the remaining larvae become devoured by the successful one or whether they are absorbed by some process of amoebocytosis cannot be definitely stated.

First stage larvae were found in parasitised caterpillars so late as May 9th.

Whether this second stage is succeeded by a number of stages differing only in size, from the stage just described, or whether the final stage larva represents the full-fed, fully developed second stage form, it is impossible to say. At any rate, from the beginning of March onwards, a range of forms can be obtained, differing only in size and development of mouthparts and forming a transition series between the stage described above and the fully developed larva lying in the empty skin of the host caterpillar.

This full grown final stage larva (Pl. v, fig. 9) measures 10-11 mm. in length; the body is flexed ventrally, is dirty-white in colour and consists of a soft, inconspicuous head, and thirteen segments. Trunk-appendages practically absent. Tail is still present, but is very much reduced. In *Limnerium validum* the final stage larva is stated by Timberlake to be entirely destitute of any trace of tail appendage. The mouthparts consist of a pair of well-marked mandibles supported by chitinous ridges. Just below each mandible, on each side of a quadrangular elevation, which may possibly represent the labium, is a mamilliform structure bearing a minute pore. A pair of similar structures lies below the elevation. These four structures apparently represent spinnerets. Two faint, oval elevations some distance above the mandibles may indicate the compound eyes of the future imago.

*Pupa*.—In late April and May, the full-fed larva emerges from the empty skin of its host and spins a glistening, greyish-white cocoon,

structurally resembling thin tissue paper, and apparently composed of an inferior kind of silk. Within this cocoon, which thus forms a lining to the cocoon of the host-caterpillar, the larva proceeds to pupation. The length of the pupal stage is probably short. Larvae that were removed from their cocoons seemed incapable of spinning another, but proceeded half-way to pupation and then perished.

The interest, therefore, of the life-history described above lies in the fact that the life-cycle of the parasite corresponds so closely to that of the host. There is only one brood, the imaginal period is distinctly later in appearance than that of the Sawfly, but the first-stage larva remains dormant through the winter just as the caterpillar does.

### 3. --DIPTEROUS PARASITES OF *Nematus erichsonii*.

Four Tachinid flies have been previously recorded as having been reared from cocoons of *Nematus erichsonii*. In 1910 Mangan (2) recorded a Tachinid which he had himself determined to be *Exorista dubia*. Hewitt (1) records three such parasites, namely:—*Frontina tenthredinidarum*, Townsend reared during 1910 in St. John, New Brunswick. *Exorista crinita*, Rond. reared both at Manchester and Ottawa from 1909 onwards. *Exorista* sp. (*E. alacris* suggested) reared by Mangan in 1911.

According to the Katalog. Palaarktischen Dipteren (Vol. III.), *E. crinita* and *E. alacris* are synonyms, so that, prior to 1913, there is only a record of two Tachinids parasitic on *Nematus erichsonii* in this country. In 1913 a considerable number of specimens belonging to some species of Tachinid was reared here from Cumberland cocoons; the percentages in cocoons from various localities have already been given. Nearly all the specimens were sent to Mr. Wainwright, who identified them as belonging to the species *Zenillia pexops*, B. & B. not previously recorded from the Larch Sawfly and not previously recorded as British. As the material thus identified included specimens from the Crummock district, the locality from which the Tachinids stated by Mr. Tothill to be identical with or closely allied to *E. alacris* had been reared in 1911, it was considered advisable to submit these latter specimens to Mr. Wainwright also, and after careful comparison with the type-specimens he came to the conclusion that the specimens really belonged to the species *Zenillia pexops*. In view of the difficulty of Tachinid determination, well illustrated by this difference in opinion of two recognised experts, the single Tachinid reared by Mangan in 1910 and determined by him to be *Exorista dubia* must be looked upon with suspicion. Although Mr. Mangan now places no faith in this determination no re-identification

is possible, as the specimen was accidentally destroyed. Dr. Stewart MacDougall, however, has kindly allowed me to examine the Tachinid material bred out by him from Cumberland cocoons about the same time, and careful comparison indicates without doubt that they belong to the species *Z. pexops*.<sup>1</sup> There seems to be some grounds, therefore, for concluding that up to the present only one species of Tachinid has been reared from British cocoons, namely the species described below:—

*Zenillia (Myxexorista) pexops*, B. & B.

Mr. Wainwright states with regard to this parasite:—

"A very little known species; indeed, up to the present, I have only known of a single female, caught by me in the New Forest, and it has not yet been recorded as British. *Zenillia* is very near to *Exorista*, and the common *Phyræ vulgaris*, Fall., and consists of several species mostly known as parasites of Lepidoptera, though one species, *barbatula*, Rond, has been recorded from *Nematus geniculatus*: of course it is not unusual for parasites of Lepidoptera to be bred also from Phytophaga."

This species was described by Brauer and Bergenstamm (Denkschr. Akad. Wien., LVIII, 1891, p. 332), and assigned to the genus *Myxexorista*:—

2. Macrochaeten discal und marginal.

X. Arten von schwarzer Körperfarbe.

A. Backen breit, herabgesenket ( $1\frac{1}{3}$  Augenhöhe). Mundrand zurückweichend, Vibrissen über demselben. Profil convex wie bei *Exorista vetula* und *pexopsis*. Zweites Borstenglied wenig länger als breit. Am zweiten Ringe zwei feine, am dritten zwei stärkere Discal-macrochaeten. Erster, zweiter und dritter Ring mit marginal. Macrochaeten, die, am dritten, den ganzen Rand einnehmen. Scheitel des ♂ fast von Augenbreite. Stirnborsten regellos und überdiess 2-3 Reihen feineren Borsten. Klauen des ♂ sehr lang. Drittes Fühlerglied des ♂ reichlich 3-mal, fast 4-mal, so lang als das zweite. Taster schwarz. Schildchen schwarz. Gesicht grau. Hinterleib blaugrau mit schwarzen Segmenträndern. Kleine schwarze Art. 7 mm.

To this description the following notes upon the colouration and chaetotaxy may be added, although it must be remembered that as colouration varies so much in Tachinid flies, colour-features cannot be considered to have very great systematic value.

A species ranging from yellowish-grey to dark-grey in scheme of

<sup>1</sup> Since writing, the determination has been confirmed by Mr. Wainwright.

colouration; females tend to be lighter in colour than males. Length, 7-9 mm.

*Head*.—Space between eye in ♂ equals breadth of eye, in ♀ is less than breadth of eye; parafrontals and occiput yellowish-grey; frontal vitta black; parafacials silver-grey; antennae dark-grey; arista bare. Two pairs of erect, well-developed, vertical bristles; ocellar pair divergent, proclinate, strong, present in both sexes; frontal bristles extend to slightly beyond second antennal joint; two pairs of orbital bristles.

*Thorax*.—Greyish-yellow to greyish-black, polished; a median pair of fairly well marked longitudinal black stripes; lateral to these, a pair of triangular dark patches; below these, a pair of short black stripes tapering at each end; squamae yellowish.

Three pairs of a strong presutural acrostichal bristles, three pairs of a strong postacrostichals; three pairs of pre-dorsocentrals, four pairs of post-dorsocentrals. On scutellum, three pairs of strong marginals, one pair of weak, cruciate apicals, one pair of fairly strong discals.

*Abdomen*.—Greyish-yellow to greyish-black; first segment dark and polished; posterior margins of other segments dark; abdominal macrochaetae discal and marginal, consisting of:—One slender pairs of discals, one pair of central marginals, two pairs lateral marginals, on second segment. One strong pair of discals, two pairs of central marginals, four pairs lateral marginals on third segment.

*Life-history*.—The imagoes commenced to emerge on May 5th (1913); the majority emerged steadily between May 5th and 22nd, and then emerged in fewer numbers, the last one appearing on June 10th. Nothing is known regarding the character of the eggs and the early stage larva. It may be noted, however, that an allied species—*Zenillia libatrix*, normally a parasite of the Brown-Tail Moth in Europe—is believed by Townsend (8) to possess the leaf-oviposition habit; on the other hand, the closely allied *Phryxe vulgaris* is stated, by Vassiliev (6), to be ovo-viviparous, a female laying up to 5,000 larvae.

The various stages of the feeding larva are gone through before winter commences. Examination of Sawfly cocoons early in November, 1913, yielded numerous full-fed Tachinid larvae, each lying within the empty skin of the host, the anterior end of the larva in the posterior end of the skin. Examination in January and February yielded other specimens exactly similar in position and structure. In no case had the *Zenillia* larva pupated.

There seems no reason to doubt, therefore, that *Zenillia pexops* hibernates as a final stage larva, an exception to the general custom

in single brooded Tachinids of hibernating in the nymphal condition. The same phenomenon has been also remarked upon by Thompson (10):—"One of the most interesting modes of hibernation which we have yet discovered have been found with some forms which pass the winter as third stage larvae within the dry and otherwise empty skin of the host, emerging therefrom and pupating in the Spring. This method of hibernation we have so far observed only with two undetermined species, one a species of *Dalana*, the other infesting a European caterpillar, which is possibly *Cnethocampa processiona*." Thompson describes these resting larvae as being of a golden-yellow colour, due, he thinks, to reserve fatty material, and speaks of the hard, firm texture of the skin. This golden-yellow colour was not evident in *Zenillia* larvae, however, nor did the integument appear to be any tougher than is the condition in Muscid larvae generally.

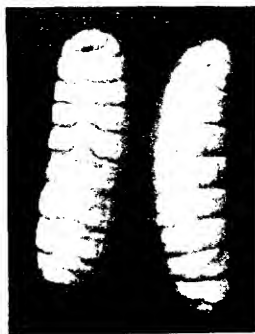


Fig. 1.—Full fed *Zenillia* larvae.  $\times 5$ .

The full-fed larva (see text figure 1, and Pl. vi, fig. 10) is cylindrical, slightly flattened dorso-ventrally, and measuring 9-10 mm. in length, by 2.5-3 mm. in breadth. Excluding the head, there are twelve segments, of which the first two are somewhat retracted. The head is small, invisible from above; the antennae, as in all Tachinid larvae, are papilliform, with two chitinous rings lying one below the other. There are two mouth-hooklets, stout and not very curved (Pl. vi, fig. 11).

The anterior margins of all segments except the first have a spinulose ring, more pronounced ventrally; anterior ventral margin of third and following segments swollen and spinulose; on fifth to tenth segment this swollen area is elevated in the median line as a spinulose,



crescentic pad; anal area (Pl. vi, fig. 10), without tubercles: stigmal pit subcircular, below it an elevated area dorsal to anus; each stigmal plate (Pl. vi, fig. 12) with three elongated slits arranged tangentially round a central button.

*Pupation.*—The larva does not emerge from the Sawfly cocoon to pupate in the ground, but pupates and forms its puparium within the cocoon. Cocoons examined late in March or early in April contain Tachinid puparia, never more than one puparium in a cocoon.

The puparium is of the usual Tachinid type, cylindrical in shape, but tapering slightly towards the posterior end, smooth, reddish in colour; 8 mm. long, by 2.5 mm. in diameter.

The exact way in which the newly hatched fly obtains exit from the Sawfly cocoon is not very clear, but examination of cocoons from which flies had emerged seemed to indicate that the fibres at the anterior end are first weakened somewhat, and then simply pushed aside by the emerging fly.

The time of emergence was, in the case of laboratory-reared specimens, ten to eleven days after pupation.

*Parasites.*—Howard's studies of the parasites of the Tussock Moth seem to indicate a greater liability to secondary parasitism on the part of such Tachinids as pupate loosely within the skin of a caterpillar, within its pupal skin, or within its cocoon. No parasites have, as yet, however, been obtained from Sawfly cocoons, which can be definitely indicated as hyperparasites of *Zenillia*. Hewitt (1) records the emergence from Cumberland cocoons in 1910 of two specimens of *Figites* sp., which he thinks may have been parasitic on Tachinids. In Wisconsin cocoons of *N. erichsonii* have yielded a specimen of *Perilampus* sp., a genus of Chalcididae, reared and recorded by Smith (11) from several Tachinidae.

#### 4.—CONCLUSIONS FROM THE ECONOMIC STANDPOINT.

It is obvious that the condition that has been present in certain Sawfly-infested Cumberland plantations during the past year, namely, the occurrence in fairly large percentage numbers of three primary parasites of *N. erichsonii* having corresponding life-history periods, and all parasitic on the same stage of the host, is not conducive to beneficial parasitism. The possibility of what Dwight Pierce has termed "accidental secondary parasitism," or to use Fiske's term, "Superparasitism," that is to say, the parasitism of one individual host by two or more species of primary parasites, or by one species more than once, must not be overlooked.

As Fiske (12) has pointed out, in the case of two such superpara-

sitic larvae in one host, one of three things may occur. In the first place, one larva may conquer the other, either directly by devouring it, or indirectly by bringing about the premature death of the host, and arrive to maturity, though often dwarfed or crippled. Secondly, both parasites may survive, in very rare cases neither the worse for the circumstances, more frequently both so seriously weakened or stunted as to materially reduce their reproductive capacity. Thirdly, neither may survive, a condition induced either by the premature death of the host, through excessive parasitism, or by the insufficiency of food.

From the economic standpoint, therefore, superparasitism in the majority of cases is just as inimical a factor in the control of a pest as hyperparasitism is.

The evidence for the existence of superparasitism on *Nematus erichsonii* is scanty, and much remains to be done.

The occurrence of several eggs or first stage Ichneumon larvae in an individual caterpillar has already been mentioned. Where the eggs or larvae numbered two or three, they were at about the same stage of development, and had undoubtedly been deposited by one female. If the number was greater, ranging from five to as many as twenty-two, the eggs and larvae were at various stages of development, and superparasitism, either by one species or two species, seemed to offer the more probable explanation.

The condition that determines which of these larvae shall proceed to pupation is chiefly, I think, one of age. Comparison of rearing results of cocoons from various localities, during 1913, showed that the earliest specimens of *Hypamblys* emerged, in nearly every case, several days before the earliest *Mesoleius*. Thus in the case of a superparasitism from both Ichneumons, the *Hypamblys* larva would, in most cases, have the advantage of a few days' start, and so would be likely to survive over *Mesoleius*. This would explain the tendency, in a locality where both *Hypamblys* and *Mesoleius* were present, for *Hypamblys* to increase and *Mesoleius* to decline.

As regards the possibility of superparasitism by Tachinid and Ichneumon, nothing can, as yet, be definitely stated. If *Z. pexops* agrees with *Z. libatrix* in possessing the leaf-oviposition habit, such superparasitism is certainly to be expected, and as *Zenillia* completes the feeding period of its life-history long before either *Hypamblys* or *Mesoleius* does, it would be more likely to survive in competition with either. That *Zenillia* may predominate at the expense of the Ichneumons seems indicated to some extent by the respective percentages of parasites in the localities, Coombe, Latrigg and Shoulthwaite during 1913. These three plantations lie in comparative proximity to each

other: they are not separated by mountain barriers. Accordingly, one would expect the percentage of parasitism in these three localities to be very similar. It may be pointed out, however, that Latrigg, with 50 per cent. of *Zenillia*, had only 19 per cent. of *Ichneumons*, whereas Shoulthwaite, with 24 per cent., of *Zenillia*, had 27 per cent. of *Ichneumons*, and Coombe, with only 18 per cent. of *Zenillia*, had 36 per cent. of *Ichneumons*. Thus the percentage of the Tachinid appears to vary inversely with the percentage of *Ichneumons*. A similar state of things would seem to be suggested by the percentage from Crummock, thus:—

		1912.	1913.
<i>Zenillia</i>	...	1.4%	2.2%
<i>Ichneumons</i>	...	24%	17%

And again by the results from Buttermere, thus:—

		1913.	1914.
<i>Zenillia</i>	...	none	32%
<i>Ichneumons</i>	...	46%	8%

Such being the case, it is desirable that future work should bear upon the question as to the respective values of *Zenillia* and the *Ichneumons* in the control of the Sawfly.

It may turn out that the undoubted powers of proliferation and of migration possessed by *Zenillia*, and its ability to withstand superparasitism by *Ichneumons*, will render it the most valuable of the three chief parasites. On the other hand, the notoriously wide range of hosts that a single species of Tachinid can affect, may prove in this case a factor that will tend to keep its numbers below the normal percentage necessary to the adequate control of the pest. That a percentage of 50 or less is insufficient under normal climatic conditions to keep the Larch Sawfly in check was evinced in 1913, by the condition of Shoulthwaite Plantation, which, though possessing 24 per cent. of *Zenillia* and 25 per cent. of *Hypamblys*, was distinctly worse in 1913 than in the previous year.

Further investigations may tend towards the conclusion that the occurrence of three parasites in comparatively large proportions in the same stage of *N. erichsonii* is a decidedly inimical factor in the natural control of the Sawfly ravages, for whether super parasitism in this case allows of the emergence of one healthy parasite, or whether, as the large proportion of shrivelled caterpillars present in cocoons during 1913 seems to indicate, the death of both host and parasites is brought about, the effect is unfavourable; leading in both cases to a material reduction in the rate of multiplication of the parasites.

In conclusion, I must express my thanks to Mr. A. B. Edwards, Mr. R. D. Marshall, Sir William Ashcroft and others, who have forwarded cocoons; to Mr. C. Wainwright and Prof. Schmiedeknecht, who have identified and given much information regarding the parasites; to Dr. C. G. Hewitt and Dr. R. Stewart Macdougall, for the loan of data and specimens, and to my chief, Professor Hickson, who has been the moving spirit in the Sawfly Investigations since their commencement in 1907.

#### 5.—SUMMARY.

1. An interesting feature of the Large Larch Sawfly investigations during 1913 has been the percentage decline in the numbers of the parasite *Mesoleius tenthredinis*, formerly so prevalent.

2. This decline has not in every case corresponded to a decline in the numbers of the Sawfly, but has been accompanied by the appearance in comparatively large numbers of two previously unrecorded parasites, viz.:—

3. *Hypamblys albopictus*, Grav., an Ichneumon closely related to *Mesoleius*, and having corresponding life-history stages, though emerging possibly a few days earlier. *Hypamblys* hibernates as a first stage larva.

4. and *Zenillia pexops*, B & B., a Tachinid fly, probably the same parasite that has previously been recorded at various times since 1910 as *Exorista crinita*, *Exorista alacris*, and *Exorista dubia*. *Zenillia* is exceptional, for a Tachinid, in hibernating as a final stage larva. It pupates and forms its puparium within the cocoon of the Sawfly, and emerges about the same time as the host.

5. As *Zenillia* appears to predominate at the expense of the Ichneumon parasites, it is important that future work should bear upon the question of the respective values of the various parasites in the control of the Sawfly.

#### AUTHORITIES REFERRED TO IN THE TEXT.

1. HEWITT, C. G.—The Large Larch Sawfly (*Nematus erichsonii*). Dominion of Canada, Dept. of Agric., Bull. No. 10, 1912.
2. BOARD OF AGRIC. AND FISHERIES.—Annual Report of the Intelligence Division. Part II. 1913.
3. MINGAN, J.—Some Remarks on the Parasites of the Large Larch Sawfly (*Nematus erichsonii*). Journ. Econ. Biol., vol. v, 1910.
4. CAMERON, P.—Monograph of British Phytophagous Hymenoptera. Vol II. Ray Society Monograph, 1885.
5. TIMBERLAKE, P. H.—Technical results from the Gipsy Moth Parasite Laboratory. V. Experimental Parasitism:—

- Study of the Biology of *Limmerium validum*. U.S. Dept. of Agric. (Bureau of Entom.), T.S. 19. Pt. v, 1912.
6. SEURAT, L. G.—Étude des Hyménoptères entomophages. Ann. Sci. Nat. Zool., T. x., 1899.
  7. RATZBURG.—Die Ichneumoniden der Forst Insekten. 1884.
  8. TOWNSEND, C. H. T.—A Record of Results from Rearings and Dissections of Tachinidae. U.S. Dept. of Agric. (Bureau of Entom.), T.S. 12, part 6, 1908.
  9. VASSILIEV, I. V.—*Dendrolimus pini*, L., and *Dendrolimus segregatus*, Butl., their life-history, injurious activities and methods of fighting them. Memoirs of Bureau of Entom. of Sci. Committee of Central Board of Land Administration and Agric., St. Petersburg, V, No. 7, 1913. (Abstract in Review of Applied Entom., April, 1914).
  10. THOMPSON, W. R.—Notes on the Pupation and Hibernation of Tachinid Parasites. Journ. Econ. Entom., vol. 3, No. 3, 1910.
  11. SMITH H. S.—Tech. Results from the Gipsy Moth Parasite Laboratory. IV.—The Chalcidoid genus *Perilampus* and its Relations to the Problem of Parasite Introduction. U.S. Dpt. Agric. (Bureau of Entom.), T.S., No. 19, pt. iv.
  12. FISKE, W. F.—Superparasitism; an Important Factor in the Natural Control of Insects. Journ. of Econ. Entom., vol. 3, Feb., 1910.

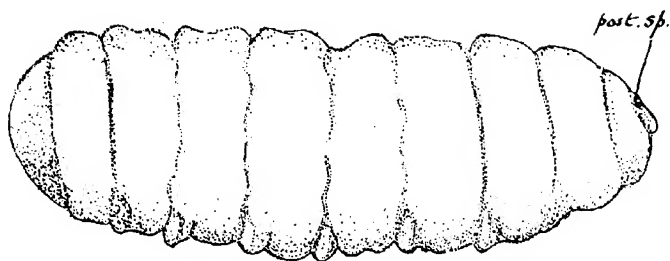
## EXPLANATION OF PLATES IV-VI.

Illustrating Mr. R. A. Wardle's paper on the "Life-histories of *Zenillia pexops*, B. and B., and *Hypamblys albopictus*, Grav."

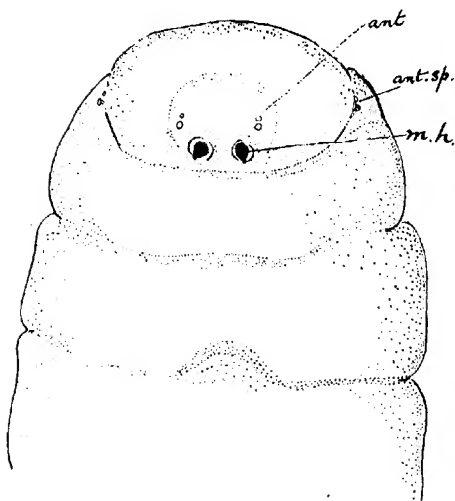
- \*Fig. 1. *Hypamblys albopictus*, imago.  
 Fig. 2. Developing egg of *Hypamblys*. Lateral view  $\times 160$ .  
 Fig. 3. ditto Later stage  $\times 160$ .  
 Fig. 4. ditto Shortly before hatching  $\times 180$ .  
 Fig. 5. Newly hatched larva of *Hypamblys*, to show tracheal system.  $\times 200$ . g. gut. a. anus. p.c. Prothoracic commissure.  
 Fig. 6. 1st stage larva—full grown.  $\times 30$ .  
 Fig. 7. Ventral view of same.  $\times 120$ .  
 Fig. 8. Second stage larva.  $\times 20$ .  
 Fig. 9. Final stage larva.  $\times 10$ .  
 Fig. 10. Full grown larva of *Zenillia pexops*, lateral view.  $\times 11$ .  
           *post. sp.* posterior spiracles.  
 Fig. 11. Antero-ventral view of same.  $\times 25$ . *ant.* antennae. *ant. sp.* anterior spiracle. *m. h.* mouth hooks.  
 Fig. 12. Posterior end of full fed larva of *Zenillia*. *st.* stigmatic plates.  
 Fig. 13. Stigmatic plates of full grown larva of *Zenillia*.

---

\* Drawn by Miss Dust, Manchester School of Art.



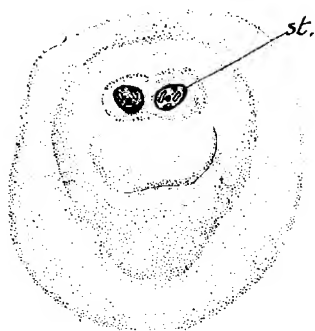
10



11



13





# A CONTRIBUTION TO THE BIOLOGY OF SEWAGE DISPOSAL.

By J. W. HAIGH JOHNSON, B.Sc., F.L.S.,

*Chemical Biologist to the West Riding of Yorkshire Rivers Board, Wakefield.*

(WITH 6 FIGURES.)

DURING recent years the problem of sewage disposal has become very urgent, especially in populous inland localities, but even rural districts have now been compelled to adopt some definite system of treating their refuse. In the early days this refuse was dealt with by natural means, being applied directly to the land, and there devoured by various forms of animal and vegetable life. Later, as the problem became more acute, chemical means were called into requisition, and substances under various names (usually containing salts of iron or alumina) were used to precipitate the polluting matters from the sewage, lime often being added to assist this precipitation. Although by this means clear effluents could be obtained, it soon became evident that the enormous volume of sludge or mud thus produced entailed a very heavy expense in disposal, and the effluent obtained, although at times clear, often needed further treatment (filtration). Filters in some form or other therefore became an essential part of almost every kind of artificial sewage treatment. The modern sewage filter, however, is not, as might be supposed, a fine-meshed strainer of some inert material, such as stone, gravel, clinker, etc., but consists of rough, often large-sized pieces. The filtering capacity depends not upon the fineness of the material, but upon the slimy or gelatinous growth (*Zoogloea*) which develops on the filter when sewage is applied. These *zoogloea* masses form a suitable nidus for the further development of fungal and other forms of life, which further ramify among the filtering material, and thus produce a fairly efficient *mechanical* strainer; but this is not all, for the *zoogloea* masses can, under certain conditions, absorb soluble polluting substances from the liquid passing over them, so that the action of such a filter is not merely mechanical straining, but effects, more or less, efficient chemical purification.

The chemical evidence of this purification is to be found in the reduction of the "oxygen absorbed"<sup>1</sup> figure and in the decomposition

<sup>1</sup>This term has a definite chemical meaning, namely, the amount of oxygen absorbed, under stated conditions, by the liquid from an acid solution of potassium permanganate, but for ordinary purposes it may be regarded as affording some indication of the amount of purification (oxidation) which is still possible.

[Journ. Econ. Biol., October, 1914, vol. ix, No. 3.]



of complex nitrogenous matters which gives rise, first to ammonia, which may later become further oxidised into nitrites, and finally into nitrates. These chemical changes are essentially those due to oxidation, and it is interesting from a biological standpoint to note that recent experiments in sewage purification attempt to effect this oxidation by blowing air through sewage mixed with a biologically active sewage sludge.

The line of development of such filters has naturally been determined by this power of oxidation, and, consciously or unconsciously, the form eventually selected has been that which most favours the development of a wide range of organisms of both animal and vegetable origin. In fact, the modern sewage filter may now be regarded as an attempt to concentrate the natural agencies of purification into small compass. This intense concentration naturally renders them particularly sensitive to external influences. The whole subject forms a most interesting biological study of great practical importance, which may be conveniently treated under the following heads:—

1. Historical account of the development of the modern sewage (sprinkler) filter.
2. Organisms as an index of pollution.
3. Ecological associations and distribution of organisms in a sewage filter.
4. Some noteworthy dominant organisms occurring on sewage filters.
  - a. The Sewage or moth-fly (*Psychoda*).
  - b. The water springtail "*Podura*," *Achorutes viaticus* (L.), Tulb.
  - c. Other dominant or sub-dominant organisms.

#### 1. HISTORICAL ACCOUNT OF THE DEVELOPMENT OF SEWAGE FILTERS.

Considering the prime necessity for disposing of the waste products of domestic life, it is somewhat surprising that, until quite recently, there was little or no improvement on primitive methods of dealing with this refuse. Probably the most advanced system of sanitation previous to the changes introduced in the nineteenth century is to be found in the Mosaic law. Attention was not, however, particularly attracted to these matters until the people gathered together in large and settled communities. In England this became marked about the middle of the eighteenth century, and during the succeeding decades conditions in the neighbourhood of dwellings became so intolerable that relief was generally sought by constructing drains to carry off sewage into cess-pools or into the nearest watercourse. During the early portion of

this period, on account of the small size of the towns and the slow-flowing nature of the ditches and smaller watercourses, the amount of pollution which eventually reached the larger streams and rivers was consequently small, and rarely, if ever, in excess of the requirements of the animal life incidental to such waters. Indeed, the reputation of many ancient fishing grounds is directly attributable to this adequate food-supply. Later, as the size and numbers of these communities increased, naturally the amount of pollution similarly increased. The most marked increase, however, occurred about the middle of the nineteenth century, and is contemporaneous with the introduction of the rapidly discharging sewers of the water-carriage system of drainage and the increased discharge of poisonous trade refuse. The effect of the above system on the condition of the streams was most marked, for not only did the sewers carry relatively more of the pollution of a district into the streams, but effected this discharge so rapidly that the sensible amount of purification formerly occurring in the ditches and dykes was minimised, while, on the other hand, the increased amount and poisonous character of the trade waste destroyed many of the natural agencies which normally assisted purification; under such exigencies it is not surprising that many of our streams rapidly degenerated into a condition which was little better than that of open sewers! From this time onwards the problem of sewage disposal may be said to have been ever present, but it is only during the last twenty years that rapid strides have been made towards its proper understanding and practical solution.

It is worthy of note that this progress could never have been so rapid had it not been for the advanced state of general scientific knowledge at the time when the sewage problem became acute. The starting point, so far as concerns this subject, may be said to be the construction in 1675, by Antony Leuwenhoek, of a microscope sufficiently powerful to reveal the presence of minute organisms in water and putrefying fluids. But it was not until 1743 that Baker indicated the scavenging powers of infusoria and many bacteria, and in 1839, Schwann and Schultze proved that micro-organisms were the true agents of decomposition. There seems, however, to have been no attempt to make use of this knowledge in explaining the purification of sewage either when discharged into rivers or thrown upon land. It is true that from very early times sewage was thus disposed of, and was then found to disappear or to lose its polluting character, but it was generally assumed that sewage thus utilised on land was directly absorbed by the growing crops, or when discharged into rivers that it underwent a process of destruction by direct oxidation.

The Sewage of Towns Commission, appointed in 1857, reported that the best method of disposing of sewage was to convey it outside the towns and there apply it to the land, and the same recommendations were repeated by the Royal Commissions of 1865 and 1868. Sir Edward Frankland was a member of the 1868 Commission, the labours of which may be described as the beginning of the application of science to the problem of sewage disposal. Frankland studied the principles upon which the land treatment of sewage depends, and evolved the method known as intermittent downward filtration. In the Second Report of the above Commission, issued in 1870, he described the process taking place in soil, when used as a sewage filter, as being not merely mechanical but also chemical, and concluded "that the process of purification was essentially one of oxidation, the organic matter being to a large extent converted into carbonic acid, water, and nitric acid, and hence the necessity for the continual aeration of the filtering medium, which is secured by intermittent downward filtration, but entirely prevented by upward filtration." He very aptly compared the action of the soil with that of the lungs, and spoke of the "respiration" of the filters"; but it would appear that in spite of the work of Baker, Schwann, and Schultze, he had no idea of the function of living organisms in this oxidation process. It is to be noted, however, that he emphasised the importance of thorough aeration, and it is not surprising that later investigators gave considerable attention to this matter.

Long before Frankland's time it was known that when organic nitrogenous bodies are applied to the soil, the nitrogen becomes eventually converted into nitrate, but it was reserved to Muller in 1873 to indicate, and to Schloesing and Muntz in 1877 to demonstrate that this nitrification process is due to bacteria. In 1882, Warington showed that this change takes place chiefly in the upper six inches of the soil. The destruction of these organic matters is not entirely restricted to bacteria, and in 1883 Dr. Sorby clearly demonstrated this fact in his evidence before Lord Bramwell's Commission on the Metropolitan Sewage discharge. He showed that the sedimentary faecal matter in the River Thames disappeared, and was replaced by small rounded particles, which were the excrement of Entomostraca. He also found large numbers of crustaceans (fresh-water shrimps) and of small annelids and other mud worms actively devouring the deposits from the sewage, thus establishing the important fact that organisms of a higher order than bacteria act as sewage scavengers. In 1886 Dr. Dupré suggested the cultivation of such organisms and their discharge along with the polluting liquid.

During the years 1888 and 1889 the Massachusetts experiments,

were in progress at Lawrence, U.S.A., and the publication of the results in 1890 stimulated the interest of sanitarians throughout this country. The experiments were undertaken for the purpose of determining the fundamental principles of filtration of sewage and of learning what can be accomplished by filters made of different materials. Special attention was devoted to the nitrification process in filters constructed of gravel, sand, and soil, and it was stated that the purification of sewage was due to micro-organisms, by which nitrifying organisms are apparently meant. The importance of the rôle played by the larger organisms spoken of by Dr. Sorby and Dupré seems again to have been overlooked.

The stimulating effect of these Massachusetts experiments is well demonstrated by the crop of new or improved devices brought forward within the next few years. Thus, in 1891, Waring patented a filter, in which even distribution was secured by means of a layer of fine material, and aeration by means of a mechanical blower. In the same year, Scott-Moncrieff constructed his cultivation bacteria-bed, which depended upon (1) the presence in sewage of bacteria which are capable of peptonising (digesting) the organic matter which it contains, (2) the indefinite multiplication of these organisms in suitable environment, and (3) the fact that in nature organic refuse is destroyed by the same means.

About this time, J. Corbett, at Salford, constructed percolating filters with spray distributors, using crushed clinker or cinders ( $\frac{1}{2}$  in. to  $\frac{3}{4}$  in.) as medium. He secured ventilation by means of numerous under-drains, and by working the beds intermittently, allowed thorough aeration during the resting period.

In 1892, Dibdin, carrying out experiments at Barking, devised the contact bed method of treatment, and again emphasised the necessity for aeration. He attained this by quite a different method from that of Corbett, and used water-tight tanks containing coke, which he kept filled with sewage for a definite period, during this period the air which remained attached to the submerged material served to assist in the oxidation and purification of the sewage. When this period of contact was ended the tank was emptied, and the coke then allowed to drain for some time before the tank was refilled; this latter procedure again allowed air—the essential factor in all such purification processes—to penetrate and reach the organic matter and living organisms which developed on the surfaces of the material.

Lowcock, in 1893, used a filter to which air was supplied by mechanical means, being blown through pipes laid in the material of the filter.

In 1897, Colonel Ducat constructed a percolating filter similar in

principle to that of Corbett, but used a different method of distribution, and advocated that the filter should be covered in and warmed so as to assist the development of the organisms.

In 1894, Corbett experimented with rotating sprinklers, and in 1898, Whittaker and Bryant constructed filters fitted with these at Accrington.

By this time, it may be considered, the main principles of sewage treatment had been fully realised, and since then any modifications in the application of these principles have been chiefly in details of construction, but latterly the fact that larger volumes of sewage can be treated per cubic yard of filtering material on sprinkler filters than in contact beds has greatly favoured the adoption of the former.

While sewage works' engineers were busy experimenting and devising the most efficient form of artificial filter, a considerable amount of work in connection with the study of the bacterial processes involved was carried out by different observers. In the Massachusetts Report of 1890, the presence of enormous numbers of bacteria in the filtering medium was noted, and, as Warington found in the case of soil, they were infinitely more numerous in the upper portion of the filter. It was pointed out that filtration through fine sand beds or soil reduced the total number of bacteria in a sewage, in some cases as much as 99 per cent.

In 1898, the London County Council issued a report dealing in a general manner with the bacterial flora of the Barking and Crossness sewages. In the same year a report giving results of the treatment of the Crossness sewage on coke beds was very disappointing from a bacteriological point of view, for, although marked purification had been effected from a chemical standpoint, yet little or no improvement was discernible either in the quantity or character of the bacteria in the effluent. It was obvious, therefore, that whatever purification the coke beds effected, they afforded not the least protection bacteriologically.

The seriousness of this danger seems to have been readily realised, and it is not surprising to find that the Second Report of the Royal Commission issued in 1902 dealt almost entirely with bacteriological problems. This Report commences with an investigation into the "Oxidation of Sterile Sewage," by Colin C. Frye, and the conclusion arrived at is that the oxidation of sewage containing no bacteria is very slow and that the chemical oxidation due to the oxygen in the atmosphere is inappreciable. Among other matters this Report also dealt with "The Discovery of Anthrax in Yeovil Sewage," "The Longevity of Typhoid Bacillus in Sewage," "The Self-purification of the River Severn," and "The Effect of Filtration in reducing the number of Bacteria in Sewage Effluents."

The view then taken of the importance of the part played by bacteria in sewage purification is summed up by Dr. McGowan in the above Report of 1902, who quotes from a report of the experts consulted by the Manchester Corporation :—" Thus, for the destruction of impurity, *i.e.*, for the real purification of sewage, there is only one practical means available, *viz.*, the employment of bacteria in some shape or form. In fact, all the methods of sewage purification actually practised are bacterial methods, whether so named or not."

In 1900 Dunbar formulated his absorption or adsorption theory, according to which the biological purification of sewage is commenced by the adsorption or deposition of solid matters from the sewage on to the surface of the filter material, and is continued by repeated absorption of these solid matters, followed alternately by oxidation occurring directly or through the action of enzymes and micro-organisms, assisted by higher plants and animals.

Some five years later Travis went so far as to say that the action of sewage filters was a purely physical operation, and denied " that the purification process is in any sense of the word, or under any circumstances, the result of bacterial action." He stated that micro-organisms are merely incidental and their action only ancillary to the actual purification, and compared their function to that of rats in the sewers. Another mechanical theory in which little or no importance was attributed to bacterial action, was that of Bredtschneider, but few have adopted the views of these two latter observers.

As stated, nearly all investigations of the sewage problem seem for many years to have quite overlooked the function of the larger (*macroscopic*) organisms such as those mentioned by Sorby and Dupre; but in 1900, Dunbar drew special attention to the function of higher plants and animals, and later, in 1907, Höfer went more fully into the scope of their action. In 1904, Dibden also pointed out the large number of active insects and annelids at work on the mud deposited on the surfaces of the material in his slate beds.

Although, as previously stated, all purification results in the oxidation of the polluting substances, yet this process of oxidation is by no means a simple one, and two phases at least are recognisable: - (1) The separation or deposition of solid matter both from suspension and also from colloidal solution, and (2) the oxidation of such deposited solids. However distinct these two phases may at first sight appear to be, it is most probable that solution and dissolution rapidly alternate, so that they intimately co-operate in the general process of purification, and generally speaking, sewage purification cannot be effected without causing the permanent separation of solid matter in some form or other.

During the initial stages of purification a large amount of solid matter is separated out, and it is with the removal and oxidation of this that the chief difficulties of sewage purification arise. These separated solids containing, as they do, much unoxidised carbonaceous and nitrogenous material, are available as a food supply for a wide range of organised life such as bacteria, and macroscopic organisms belonging to both the vegetable and animal kingdoms.

The engineers and others who have devised the various forms of filter beds have consciously or unconsciously chosen those forms which favour the most efficient combination of these agencies, and the ideal filter bed may be said to be one which best preserves (a) a balance of maximum efficiency between the active surface for the absorption and retention of solids, and (b) the development of the animal and vegetable life most useful for the destruction of the organic matters thus deposited. These two factors act antagonistically, and the balance between the quantity of deposited and retained solids needs to be carefully adjusted to the requirements of the animal and vegetable life which it supports, as an undue increase of the former may act very deleteriously upon the latter—by choking up the filter and so prevent the circulation of air, with consequent death of the organisms. The filter then rapidly becomes waterlogged or “ponded,” and purification deteriorates in consequence. From the difference in the mode of use of a contact bed and a percolating filter, the species of organisms found in them naturally show considerable differences. In the contact bed only those organisms can survive which are able to exist practically without free oxygen for some considerable portion of the period during which the bed stands full of sewage, whereas in a good percolating filter the greater portion of the filter is in direct contact with the air, and the organisms there found are those which require the presence of free oxygen.

The number and variety of living organisms to be found in sewage filters is almost inconceivable, and their study demands much greater attention than it has hitherto received. In the following pages an attempt will be made to describe some of the principal organisms found, and their methods of growth, and to discuss the reasons for their special abundance in some cases and their infrequency or absence in others, in the hope that means may be evolved of favouring their growth when that is advisable, or checking their development when they give rise to nuisance, or even restricting their sphere of action when useful but liable to occasion nuisance from over-development.

The practical importance of these studies has been already emphasised in such cases as those mentioned by the Royal Commission of 1898 (Fifth Report, p. 221), in their experiments in checking the too

profuse growth of some of the micro-organisms and in the measures which have had to adopted by various Authorities to prevent the undue development of flies.

To facilitate this study, the City Surveyor of Wakefield, in constructing new filters at the Wakefield Sewage Works, has provided an inspection chamber in the body of the material, in which, by means of trays containing filtering medium, samples both of the growths and of

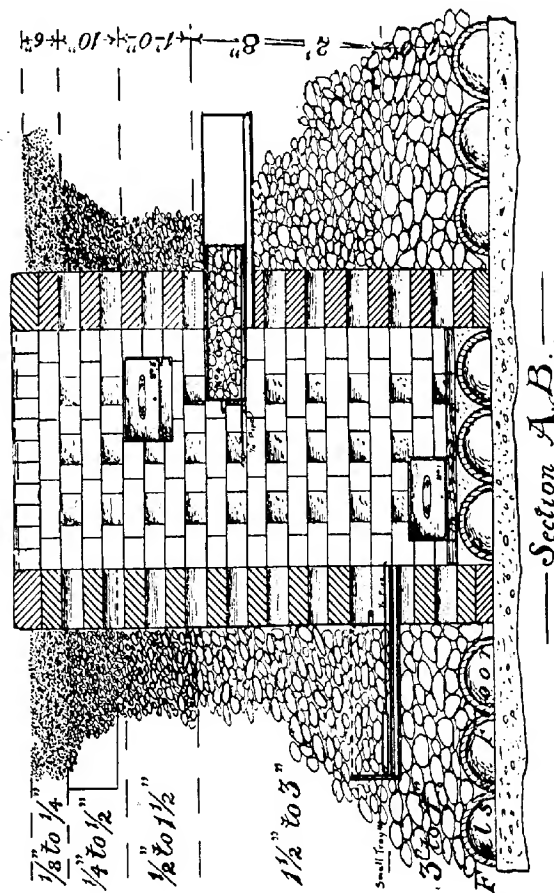


Fig. 1. Inspection Chamber in Percolating Filter at Wakefield Sewage Works.



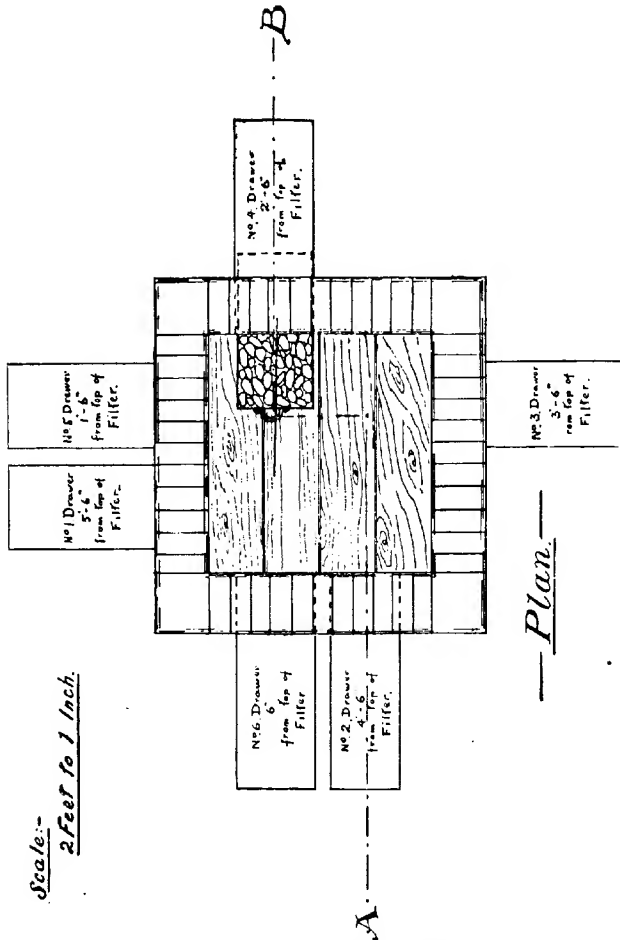


Fig. 2. Inspection Chamber in Percolating Filter at Wakefield Sewage Works.

the liquid in various stages of treatment can readily be obtained at every foot depth throughout the filter. It would be well if this example were followed in all the larger filter installations, and the accompanying plan and section (Fig. 1 and 2), will serve to illustrate the method of construction.

## 2. ORGANISMS AS AN INDEX OF POLLUTION.

Domestic sewage is naturally a very complex liquid, and contains both in solution and in suspension much readily decomposable nitrogenous and carbonaceous matter, which affords a suitable food-supply for a very large and complex flora and fauna. So very large and complex is this organisation that it would be almost impossible to enumerate the individual members occurring in such a liquid, and it is doubtful if any very good purpose would be served by so doing.

If, however, the more frequently occurring organisms be arranged according to the amount of pollution in which they occur, it will be noticed that certain forms never appear in polluted waters, while others never appear in non-polluted water; again, some have a considerable facultative range, while others are very restricted in this respect. Thus one regards the presence of certain organisms as being indicative of pollution or otherwise, and, broadly speaking, the presence of most aquatic forms of life may be regarded as being largely determined by the amount and character of the food-supply, *i.e.*, pollution. Naturally, it would be exceedingly difficult, if not impossible, to satisfactorily account for the presence or absence on this basis in *every* instance, for, obviously, many obscure points in the life-history of these organisms themselves require elucidation, while the chemistry of decomposition is so complex as to preclude any detailed study of its action upon the various stages of such life.

The more characteristic organisms may, however, be readily divided—according to the decreasing amount of pollution in which they develop—into the following three classes:

(1) Polysaprobies. (2) Mesosaprobies. (3) Oligosaprobies. The characters of these groups are:—

1. *Polysaprobies*.—These organisms inhabit the more grossly polluted waters in which reduction and decomposition of organic matters is actively taking place, giving rise to carbon dioxide and nitrogenous decomposition products with a consequent lack of oxygen. Offensive mud, blackened by sulphide of iron, is usually present, whilst diatoms and the higher forms of aquatic vegetation and fish are absent. There is abundance of lowly organised forms of life, chiefly belonging to the group *Schizomycetes*, or the lowest form of fungi; the bacteria capable of developing on gelatine may exceed one million per c.c.

2. *Mesosaprobies*.—Water in which these organisms are found is less grossly polluted than in the former case. Many of the higher water-plants flourish, and there may be considerable amounts of dissolved oxygen present. Aeration and evolution of oxygen from plant

life facilitate the existence of the larger fauna. Dissolved oxygen varies considerably in amount, but is always present. The decomposition of nitrogenous matter has proceeded further, and oxidation may have proceeded so far as to produce nitrites and nitrates. Samples of water, when incubated, do not usually putresce.

These organisms are divided into two classes, (A) those inhabiting the more polluted waters, and (B) those inhabiting the less polluted.

In the former case (A) purification processes are more vigorous. There is still an abundance of lowly organised life, but in this case, chiefly of the group *Schizophyceae*, or the blue green algae, and in running waters fungi of the higher group *Eumycetes* (or *Mycomycetes*) are to be found. Animal life is fairly abundant and fish rarely die. Bacteria capable of developing on gelatine may amount to 100,000 per c.c.

In the latter case (B) where there is less pollution, and purification is therefore less rapid, benthon (*benthos*, depths) forms of life, or those which live on the bed of the stream, are more prevalent, especially diatoms. A great variety of vegetation is found, particularly in members of the group *Chlorophyceae*, or the green algae.

3. *Oligosaprobies*.—These organisms occur in waters of great purity, where the organic nitrogen has been almost completely mineralised. The "oxygen absorbed" figure is low, and in consequence the rate of absorption of dissolved oxygen is very slow. The water has a slightly alkaline reaction and is highly transparent, and any mud present contains little organic matter. Polysaprobic forms are quite absent, but there is a great variety of animal and vegetable life. The representatives of the flagellate group Peridinales are more numerous, and of plant life members of the group Charales, which are very sensitive to pollution, begin to appear.

It will be seen from the above classification that there is a progressive increase both in the relative numbers and variety of the higher forms of life as we pass from the most to the least polluted waters, and also that the presence of green algal forms of life (*Chlorophyceae*), marks an advance in the purity of the water, so that in polluted streams there is a lack of that green colour so characteristic of the life found in natural watercourses.

The following list gives some of the more characteristic organisms arranged according to the pollution intensity; in each division the vegetable organisms precede those of animal origin.

1. POLYSAPROBES.

*Schizomycetes.*

- Spirillum undula*, Ehrbg.
- „ *rugula* (O. F. Müller).
- Sphaerotilus natans*, Kütz.
- Zoogloea ramigera*, Itzigohn.
- Beggiatoa alba* (Vaüch.), Trev.
- Chromatium okenii* (Ehrbg.), Perty.
- Lamprocystis roseo-persicina* (Ktz.), Schröter.

*Schizophyceae.*

- Arthrospira jenneri*, Stütz (if with *Beggiatoa*, etc.).

*Euglenales.*

- Euglena viridis* (if very abundant).

*Flagellata.*

- Bodo putrinus* (Stokes), Lemm.

*Ciliata.*

- Paramacium putrinum*, Cl. u. L.
- Vorticella microstoma*, Ehr.
- „ *putrina*, O. F. Müller.

*Vermes.*

- Tubifex rivulorum*, O. F. M.

*Diptera.*

- Eristalis tenax*, L. Larvae.

2. MESOSAPROBES.

A. (strong).	B. (weak).
<i>Schizomycetes.</i>	<i>Schizomycetes.</i>
<i>Sphaerotilus natans</i> (if with diatoms and <i>Cladotrix</i> forms).	<i>Cladotrix dichotoma</i> , Cohn.
<i>Thiothrix nivea</i> (Rab.), Win.	<i>Schizophyceae.</i>
<i>Chromatium okenii</i> (Ehr.), Perty.	<i>Oscillatoria limosa</i> , Ag.
<i>Lamprocystis roseo-persicina</i> (Ktz.), Sch.	<i>Euglenales.</i>
	<i>Euglena acus</i> , Ehrbg.
	„ <i>spirogyra</i> , Ehrbg.
	„ <i>deses</i> , Ehrbg.
<i>Schizophyceae.</i>	<i>Phacus caudata</i> , Hübner.
<i>Oscillatoria tenuis</i> , Ag.	<i>Bacillariales.</i>
„ <i>formosa</i> , Bory.	<i>Melosira varians</i> , Ag.
<i>Arthrospira jenneri</i> , Stütz. <sup>1</sup>	<i>Diatoma vulgare</i> , Bory.

<sup>1</sup> If associated with algae.

<sup>2</sup> See also Polysaprobies.

- A. (strong).  
*Phormidium autumnale* (Ag.), Gomont.  
*Euglenales*.  
*Euglena viridis* var. *lacustris*, France.  
*Bacillariales*.  
*Hantzschia amphioxys* (Ehr.), Grun.  
*Nitzschia palea* (Ktz.), W.Sm.  
*Stauroneis acuta*, W.Sm.  
*Protococcales*.  
*Stichococcus bacillaris*, Naeg.  
*Confervales*.  
*Ulothrix subtilis* (Ktz.).  
*Myxomema tenue* (Ktz.).  
*Prasiola crispa* (Lightf.), Menegh.  
*Phycomycetes*.  
*Leptomitus lacteus*, Ag.  
*Enascomycetes*.  
*Fusarium aurantiacum*, Sacc.  
*Flagellata*.  
*Oicomonas termo* (Ehr.), Kent.  
*Monas vivipara* (Ehr.).  
 „ *vulgaris* (Cienk), Senn.  
 = *M. guttula*, Ehr.  
*Anthophysa vegetans* (O.F.M.), Bütsch.  
*Peranema trichophorum* (Ehr.), St.  
*Chilomonas paramaccium*, Ehr.  
*Ciliata*.  
*Urotricha farcta* (Ehr.), Cl. u. L.  
*Colpidium colpoda*, Stein.  
*Paramaccium caudatum*, Ehr.  
*Stentor coerules*, Ehr.
- B. (weak).  
*Synedra ulna* var. *spendens* (Ktz.).  
*Navicula reibissonii*, Ktz.  
 „ *cryptosephala*, Ktz.  
*Navicula cuspidata*, Ktz.  
 „ *mesolepta*, Ehr.  
 „ *amphisbaena*, Bory  
 „ *ambigua*, Ehr.  
*Gomphonema olivaceum*, Ktz.  
 „ *parvulum*, Ktz.  
*Rhoicosphenia curvata* (Ktz.), Grun.  
*Nitzschia communis*, Rabh.  
*Surrella ovalis*, Bréb. v. *ovata*.  
 = *S. ovata*, Ktz.  
*Conjugatae*.  
*Closterium acerosum*, Ehr.  
 „ *peracerosum*, Gay.  
*Protococcales*.  
*Stichococcus bacillaris*, Naeg.  
*Scenedesmus quadricauda* (Turp.), Bréb.  
*Confervales*.  
*Ulothrix subtilis* (Ktz.).  
 cf. *Oligosaprobes*.  
*Tribonema bombycina*, Derb.  
 Sol.  
*Edogonium*, species.  
*Cladophora crispata*, Ktz.  
*Vaucheria sessilis*, (Vauch.), D.C.  
*Monocotyledonae*.  
*Holodea* (*Elodea*) *canadensis*, R. u. Mchx.  
*Lemna minor*, L.  
*Dictyoledonae*.  
*Ceratophyllum demersum*, L.

A. (strong).	B. (weak).
<i>Carchesium lachmanni</i> , Kent.	<i>Rhizopoda</i> .
<i>Epistylis coarctata</i> , Cl. u. L.	<i>Arcella vulgaris</i> , Ehr.
<i>Termes</i> .	<i>Centropyxis aculeata</i> (Ehr.), St.
<i>Tubifex rivulorum</i> , O.F.M.	<i>Heliozoa</i> .
<i>Rotatoria</i> .	<i>Actinophrys sol</i> , Ehr.
<i>Rotifer vulgaris</i> , Schrank.	<i>Ciliata</i> .
<i>Callidina elegans</i> , Ehr.	<i>Coleps hirtus</i> , Ehr.
<i>Crustacea</i> .	<i>Nassula elegans</i> , Ehr.
<i>Asellus aquaticus</i> (L.).	<i>Paramacium bursaria</i> (Ehr.),
	Focke.
<i>Diptera</i> .	<i>Stentor polymorphus</i> , Ehr.
<i>Chironomus plumosus</i> , L.	<i>Carchesium epistylis</i> , Cl.
(Larvae) (if numerous).	<i>Spongiae</i> .
<i>Psychoda phalaenoides</i> (L.).	<i>Ephydatia fluviatilis</i> (L.).
(Larvae.)	<i>Euspongia lacustris</i> (L.).
„ <i>sexpunctata</i> , Curtis.	<i>Rotatoria and Gastrotricha</i> .
= <i>Ps. phalaenoides</i> ,	<i>Melicerta ringens</i> , Schr.
Meigen. (Larvae.)	<i>Rotifer vulgari</i> , Schr.
	<i>Anuraea aculeata</i> , Ehr.
	<i>Bryozoa</i> .
	<i>Plumatella repens</i> (L.).
	<i>Crustacea</i> .
	<i>Asellus aquaticus</i> (L.).
	<i>Gammarus fluviatilis</i> , Rös.
	<i>Daphnia pulex</i> , De Geer.
	<i>Diptera</i> .
	<i>Chironomus</i> . Larvae bright
	yellow, not red.
	<i>Pisces</i> .
	<i>Gasterosteus aculeatus</i> , L.

## 3. OLIGOSAPROBES.

*Schizomycetes*.

- Chlamydothrix ochracea* (Ktz.), Mig.
- Gallionella ferruginea*, Ehr.
- Crenothrix polyspora*, Cohn.

*Schizophyceae*.

- Merismopedia glauca* (Ehr.), Näg.

*Chrysomonadales.*

Dinobryon species.

*Peridinales.*

Ceratium hirundinella, O. F. M.

Peridinium cinctum, Ehr.

*Bacillariales.*

Cyclotella meneghiniana (Ktz.

Tabellaria flocculosa (Roth.), Ktz.

Meridion circulare, Ag.

Fragilaria virescens, Ralfs.

Asterionella formosa, Hass.

Eunotia arcus (Ehr.), Rabh.

Navicula mesolepta, Ehr.

„ major, Ktz.

„ limosa, Ktz.

Gomphonema acuminatum, Ehr.

Cymbella cistula (Hempr.), Kireh.

Bacillaria paradoxa, Gmelin.

Surirella splendida, Ktz.

*Conjugatae.*

Closterium lunula, Ehr.

Mougeotia genuflexa (Dillw.), Ag.

*Protococcales.*

Eudorina elegans, Ehr.

Volvox globator, L.

Tetraspora gelatinosa (Vauch.), Desv.

Richierella botryoides (Schmid.).

Botryococcus braunii, Ktz.

*Confervales.*

Ulothrix variabilis, Ktz.

„ subtilis var. variabilis (Ktz.), Kir.

Chaetophora elegans (Roth.), Ag.

Rhizoclonium hieroglyphicum (Ag.), Ktz.

Cladophora glomerata, Ktz.

Vaucheria sp.

*Florideae.*

Lemanea torulosa (C. Ag.), Sirodot.

*Bryophyta.*

Fontinalis antipyretica, L.

Hypnum riparium, Schimp.

*Monocotyledoneae.**Potamogeton pectinatus*, L.*Ciliata.**Carchesium polypinum*, Ehr.*Hydroidea.**Hydra oligactis*, P. = *fusca*, L.,, *viridis*, L.*Rotatoria and Gastrotricha.**Notholca longispina*, Kellicott.*Mollusca.**Limnaea stagnalis* (L.).,, *peregra*, Müll.*Crustacea.**Gammarus pulex* (L.), De Geer.*Coleoptera.**Dytiscus marginalis*, L.*Pisces.**Gobio fluviatilis*, Cuv.

In the Polysaprobic zone two organisms—*Sphaerotilus natans* and *Zoogloea ramigera*—are of outstanding interest in the Flora of a sewage filter, and as they are not very frequently described in the textbooks, the following brief account may be found useful.

***Sphaerotilus natans*, Kützinger.**

In its typical form (Figs. 3 and 4) the growth occurs as slimy, tufted, felted masses attached to some submerged object in polluted streams, developing most luxuriantly in running water, which replenishes the supply of oxygen necessary to check putrefaction in masses of the growth. The colour varies from nearly pure white to dirty yellow or brown, and at times a reddish tint is observable. This organism consists of gelatinous filaments 6-8  $\mu$  thick, containing cells about 2  $\mu$  broad, and 4-6  $\mu$  long. The gelatinous sheath, which is usually of considerable thickness, is not, however, readily visible, and is not shown in fig. 4. In older specimens, however, a shrunken, brownish coloured sheath may be readily identified, often almost or quite devoid of cell contents.

Multiplication ordinarily takes place by transverse cell division or fission, but it is also said to occur by means of "swarm cells," which are liberated at the ends of the filaments.

Two other species have been described under the names of *Sphaerotilus fluitans* and *Sphaerotilus roseus*; these, however, possess





Fig. 3. *Sphaerotilus natans*, Kützing.  $\times 1$ .  
(Phot. J. W. H. J.)



Fig. 4. *Sphaerotilus natans*, Kützing.  $\times 1,000$ .  
(Del. J. W. H. J.)

but slight distinctive characters, and are probably only forms of the above.

*Sphaerotilus* can be found in almost every stream receiving considerable quantities of unpurified sewage. It also frequently occurs in great abundance in streams which receive warm effluents containing organic matter from industrial premises.



Fig. 5. *Zoogloea ramigera*, Itzigsohn.  $\times 100$ .  
(Phot. J. W. H. J.)

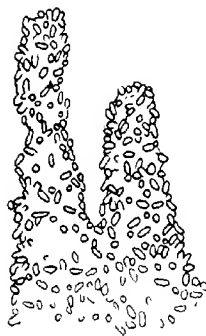


Fig. 6. *Zoogloea ramigera*, Itzigsohn.  $\times 1,000$ .  
(Del. J. W. H. J.)

***Zoogloea ramigera*, Itzigsohn.**

*Sphaerotilus* when occurring in more grossly polluted waters, often takes this form (Figs. 5 and 6). It usually occurs as a white or greyish, often branched gelatinous mass, adhering to submerged twigs, algae, etc. The branches measure about 1.0-2.0 m.m. in length and about  $15\ \mu$  in breadth, and contain rod-like cells about  $1\ \mu$  thick imbedded in the gelatinous matrix. There is a considerable variation in the thickness of the branches, and at times they are very short and thick, when the growth assumes a rounded gelatinous form. On the other hand, attenuation may be so great that the connection with the filamentous form (*Sphaerotilus*) is readily seen.

The following varieties of this organism have been noted:—

- a. compacta.* As microscopically small gelatinous masses closely packed among the type form; cells as short rods.
- b. carnea.* As flesh-coloured masses on the sides of the sewage carriers; cells  $1.5\ \mu$  thick.
- c. uva.* On stalks and roots of submerged plants in sub-globular masses varying in diameter from  $\frac{1}{4}''$ — $\frac{3}{4}''$ ; cells long and somewhat over  $1\ \mu$  thick.

(To be continued.)

## REVIEWS.

**MANUAL OF FRUIT PESTS.** By the late M. V. Slingerland and C. R. Crosby. Pp. xvi + 503 and 396 text figs. New York: The Macmillan Company, 1914. Price 8s. 6d. net.

The removal by death, in the spring of 1909, of the late Professor Slingerland, robbed the United States and the world generally of one of the most practical and far-seeing workers in economic biology, and a man whose place it will be unusually difficult to fill. He not only brought a well-trained mind and long experience to the problems he grappled with, but was gifted with a broad and practical spirit, so essential and yet so rare. His published writings are well known to all economic biologists, but as the joint-author, Mr. C. R. Crosby, informs us, a large amount of his work remained unpublished at the time of his death, including the present work, which had been commenced by him in 1908. Mr. Crosby has completed this, and given us the very admirable and practical treatise now before us.

It is one of the few works treating of the insects attacking fruit that can be strongly recommended to the practical fruit grower, for the information contained therein is concise yet clear, well illustrated, and the remedial measures recommended the outcome of a long and practical experience with the problems of insect prevention and destruction.

Many of the pests or near allies are common to this and other countries, so that it will appeal to a wide circle of readers who cannot fail but profit by a careful perusal of its pages.

**FLIES IN RELATION TO DISEASE: NON-BLOODSUCKING FLIES.** By G. S. Graham-Smith. Pp. xvi + 389, xxvii pls., 32 figs. and 20 charts. 2nd edition. Cambridge: The University Press, 1914. Price 12s 6d. net.

We welcome a second edition of this extremely valuable and interesting work. In the first edition the author stated "an attempt was made to collect, tabulate and examine critically the various facts and hypotheses relating to the life-histories, habits, and disease-carrying potentialities of non-bloodsucking flies, which had been published up to the end of the year 1912." The work published during 1913 is now treated in a similar manner, together with recent unpublished observations by the author, and numerous additional illustrations and charts.

With its great mass of facts and references, as a book of reference it should be accessible to every medical officer of health in the country, while its purely biological portions will be appreciated by all.

A REVISION OF THE ICHNEUMONIDÆ. Pt. III. Tribes Pimplides and Bassides. By Claude Morley. Pp. xiii + 148, 1 col. pl. London: British Museum (Natural History), 1914. Price 5s. 6d.

The third part of Mr. Morley's excellent revision follows on the same general lines as the two previous parts. Nearly fifty new species are described, with accompanying critical notes.

In view of the relationship between these parasites and many injurious forms of insect life, the importance of a thorough systematic revision of the Ichneumonidae cannot well be overestimated, and for such a task no one is better qualified than the present author. We look forward with considerable interest to the early appearance of further parts.

FABRE, POET OF SCIENCE. By Dr. C. V. Legros. Translated by Bernard Miall. Pp. 352 and portrait. London: T. Fisher Unwin. Price 10s. 6d. net.

Dr. Legros' interesting work can scarcely be termed a biography, for it contains very little about the actual life of Fabre; nevertheless, the various data given have proved sufficient whereon to hang a charming description of his work and methods, illustrated by copious extracts from his writings.

The only criticism we would offer, and it recurs again and again to the mind as one reads this book, is that Fabre had an overestimated idea of the value of his work, and was ill-equipped by lack of training. He created and lived in an unnatural atmosphere, in which almost everything he saw and described was "marvellous," "extraordinary," "immense," "brilliant," or "stupendous." "He watches at night, by the dim light of a lantern," "in unsociable silence, invisible to all, he worked," and so on, with adjectives and adverbs galore.

Dr. Legros depicts his subject rather as the showman than the shy, unsociable student of nature, and we leave the book with a feeling that we would rather have the poetical and highly-coloured descriptive writings of Fabre than the "admiring commentary" of his biographer.

THE PHILOSOPHY OF BIOLOGY. By J. Johnstone. Pp. xv + 391, 31 figs. Cambridge: The University Press, 1914. Price 9s. net.

Dr. Johnstone's work will appeal to a wide circle of readers beyond biologists; in all probability they will outnumber the biologists, for after a very careful perusal of this work we feel a sense of disappointment and that the really important parts might well have been contained in a hundred pages or so. One grows tired and weary of words and sentences that express so little, nevertheless, with patience the reader will find much of interest, that might have been more tersely and lucidly set forth.

